

Evaluation of VTO Benefits Using Large Scale Simulation

**2014 DOE Hydrogen Program and Vehicle Technologies
Annual Merit Review**

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Sponsored by Jacob Ward, David Anderson & Fred Joseck

Project ID # VAN008



U.S. Department of Energy

Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Project Overview

Timeline

- October 2014 – September 2014

Barriers

- Risk aversion*
- Constant advances in technology*
- Cost*
- Computational models, design, and simulation methodologies*
- Complex benefits analysis

*from 2011-2015 VTP MYPP

Budget

Total Project Funding (DOE)

- \$250k (Jacob Ward)
- \$250k (David Anderson)

Partners

Formal Collaborator Interactions

- All U.S. DRIVE Partners, outside companies (OEMs, suppliers...)



Relevance

1. Evaluate the impact of VTO R&D on vehicle energy consumption, cost as well as individual component operating conditions and requirements
 2. Provide inputs to multiple DOE tools for analysis
- Process is based on a 2 year cycle:
 - First year focused on performing the vehicle simulations
 - Second year on analyzing results
 - This presentation will focus on the process developed to analyze the impact of DOE developed technologies on component operating conditions and requirements to guide future R&D



Approach

Issue: Manually analyzing very large number of data sets (i.e. >4,000 vehicles) has proven cumbersome, error prone and time consuming in the past

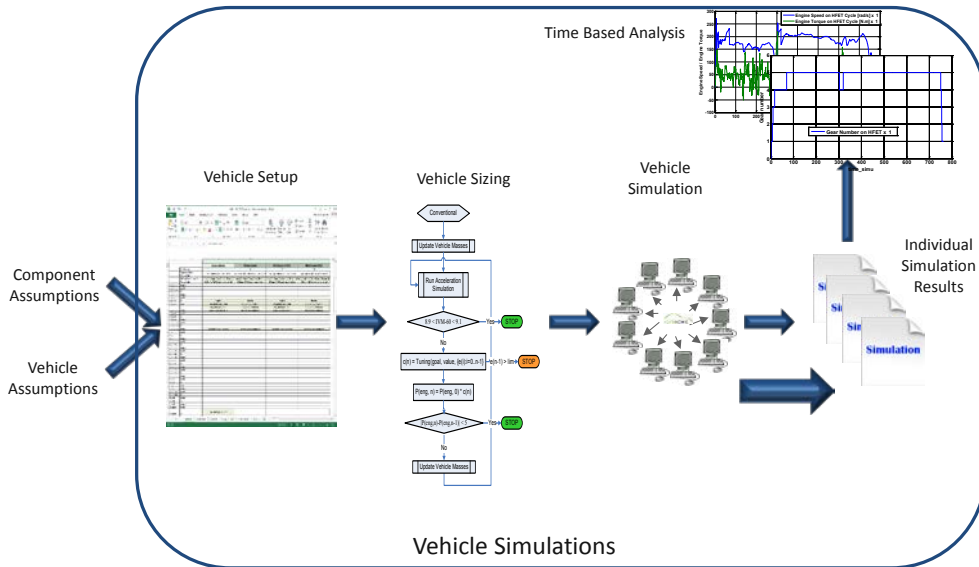
- Autonomie includes numerous post-processing tools, but they focus mostly on the data analysis of individual vehicles
- For large datasets of simulation results, the data analysis requirements are different
 - Managing lots and lots of data (number of files, disk size, access time, etc.)
 - Looking at high level indicators and spotting overall trends
 - Performing post-processing calculations without rerunning all of the vehicles

Solution: Leverage Autonomie structure to develop a new post-processing process centered around large data set analysis

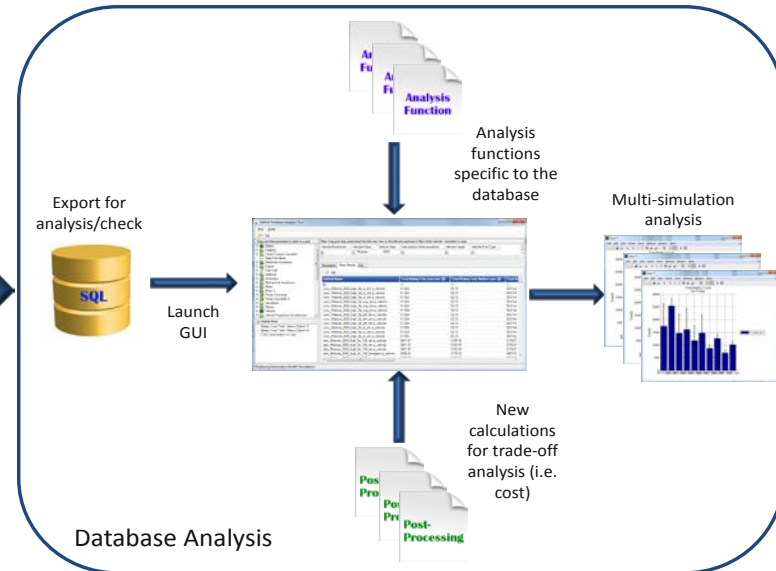


Overall Process Overview

Phase 1: Vehicle Simulations



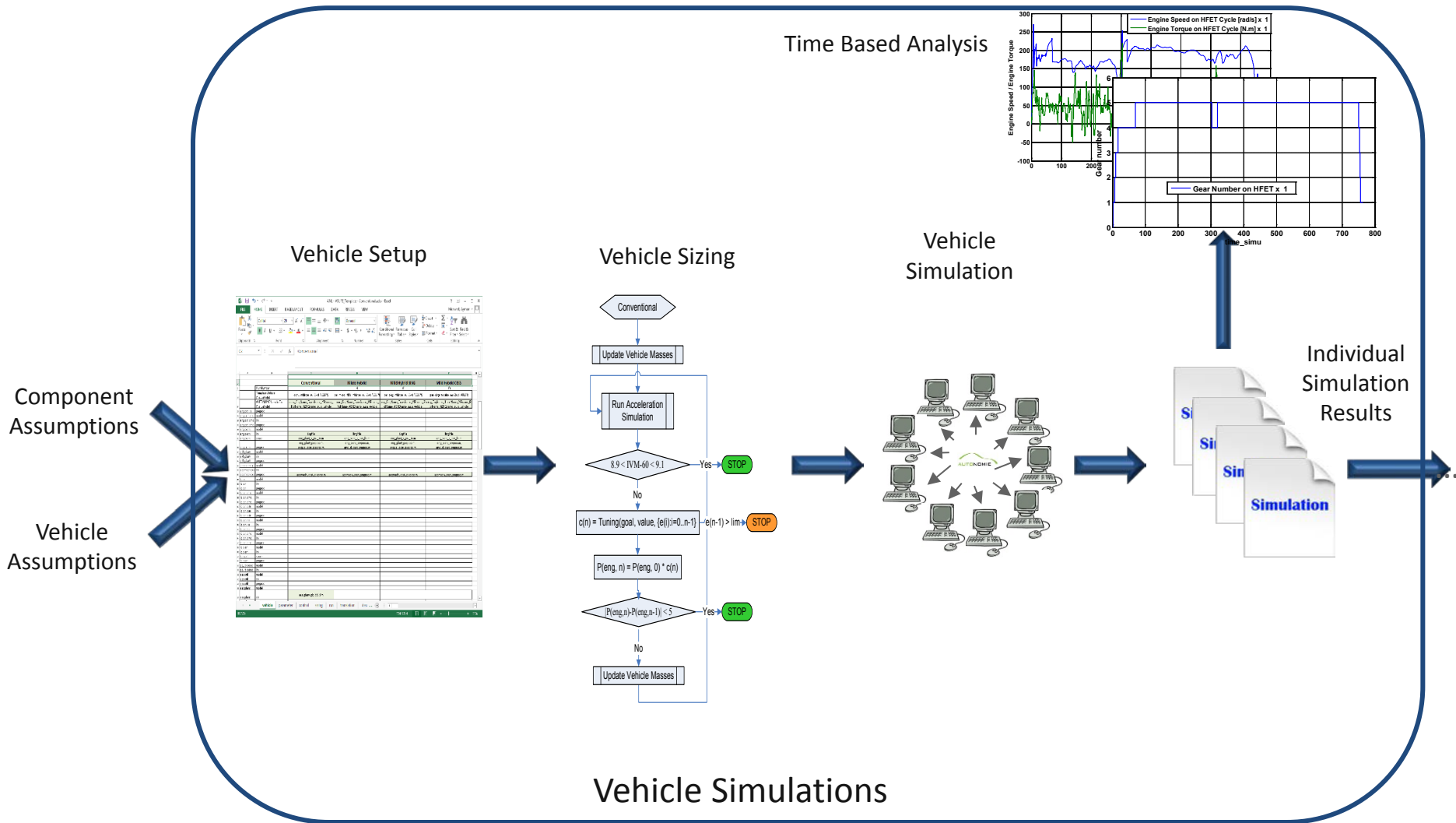
Phase 2: Database Analysis



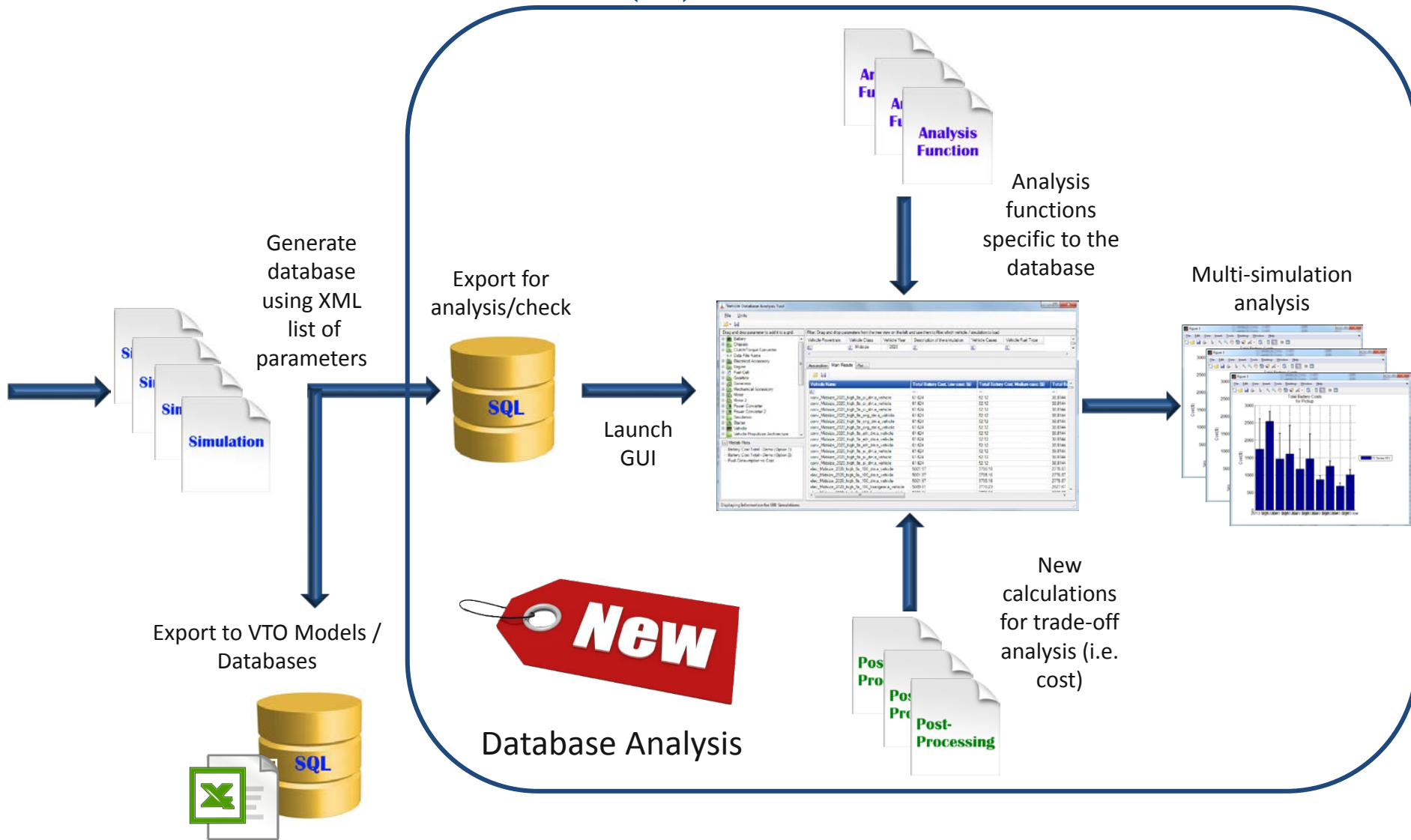
Export to Models /
databases



Process Overview (1)



Process Overview (2)



Technical Accomplishments

New Analysis Process

- A new process has been developed to generate a targeted database containing information selected by the users from a very large number of Autonomie results
- The inputs include:
 - A folder containing all of the individual Autonomie result files. For the current study:
 - 296 GB of data
 - ~7,500 individual results files
 - An XML file listing the parameters to be included in the database
- The output is an optimized database containing only the requested information. For the current study:
 - ~30 MB of data
 - ~25 minutes to generate database
- New, targeted databases can be created with any subset of any study. As a result, the same process is now used to provide inputs to multiple DOE market penetration models, BITES website, GREET...



Technical Accomplishments

Database Analysis Tool

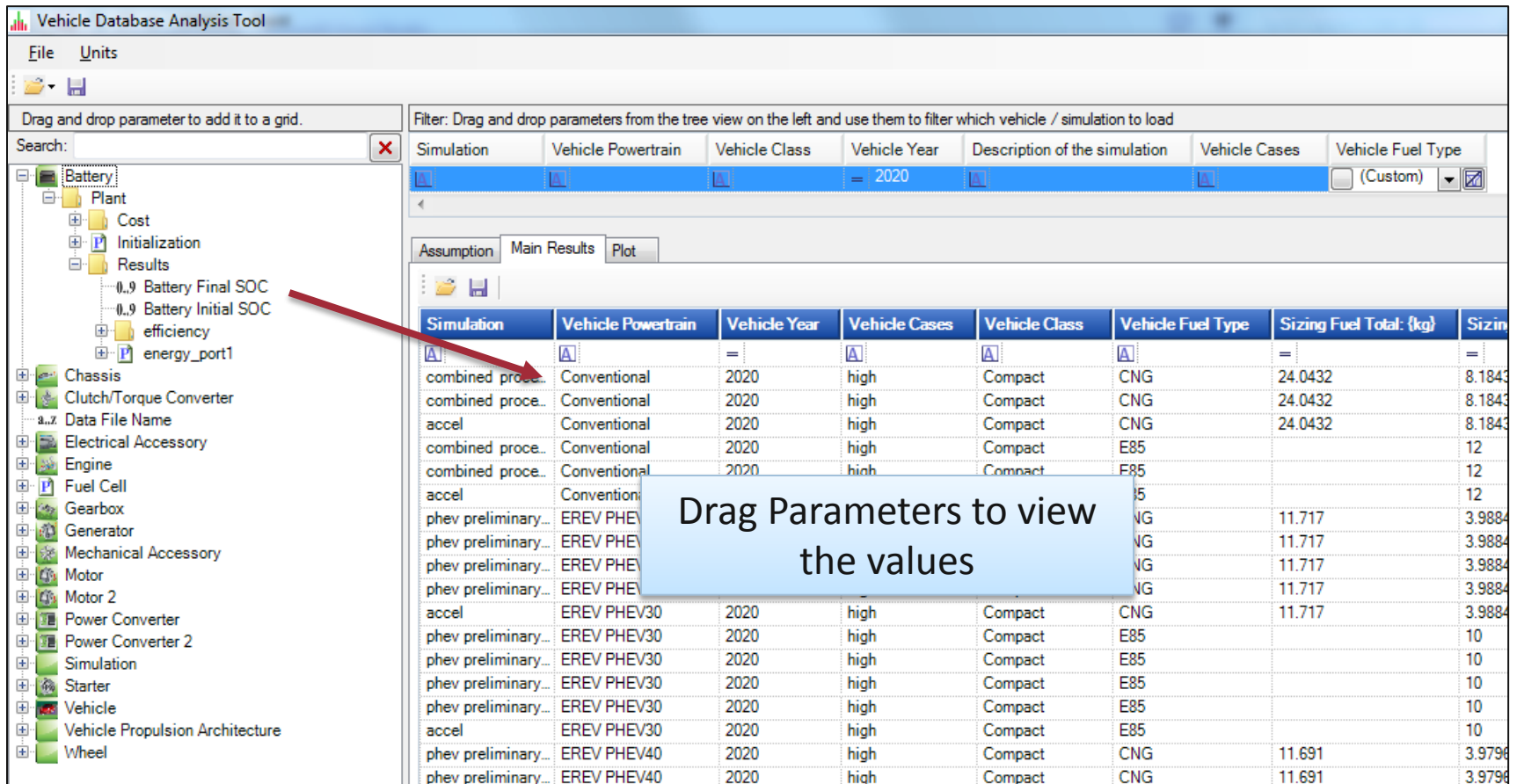
Quickly filter results of interest through filters (i.e. all results for midsize vehicle + electrified powertrain + after 2020)

[illegible]

Technical Accomplishments

Database Analysis Tool

Users can select the parameters they want to analyze through Drag & Drop



Vehicle Database Analysis Tool

File Units

Drag and drop parameter to add it to a grid.

Search: [X]

Filter: Drag and drop parameters from the tree view on the left and use them to filter which vehicle / simulation to load

Simulation Vehicle Powertrain Vehicle Class Vehicle Year Description of the simulation Vehicle Cases Vehicle Fuel Type

Assumption Main Results Plot

Simulation Vehicle Powertrain Vehicle Year Vehicle Cases Vehicle Class Vehicle Fuel Type Sizing Fuel Total: {kg} Sizing Fuel Total: {kg}

combined proc... Conventional 2020 high Compact CNG 24.0432 8.1843

combined proc... Conventional 2020 high Compact CNG 24.0432 8.1843

accel Conventional 2020 high Compact CNG 24.0432 8.1843

combined proc... Conventional 2020 high Compact E85 12

combined proc... Conventional 2020 high Compact E85 12

accel Conventional 2020 high Compact E85 12

phev preliminary... EREV PHEV 2020 high Compact CNG 11.717 3.9884

phev preliminary... EREV PHEV 2020 high Compact CNG 11.717 3.9884

phev preliminary... EREV PHEV 2020 high Compact CNG 11.717 3.9884

phev preliminary... EREV PHEV 2020 high Compact CNG 11.717 3.9884

accel EREV PHEV30 2020 high Compact CNG 11.717 3.9884

phev preliminary... EREV PHEV30 2020 high Compact E85 10

phev preliminary... EREV PHEV30 2020 high Compact E85 10

phev preliminary... EREV PHEV30 2020 high Compact E85 10

phev preliminary... EREV PHEV30 2020 high Compact E85 10

accel EREV PHEV30 2020 high Compact E85 10

phev preliminary... EREV PHEV40 2020 high Compact CNG 11.691 3.9796

phev preliminary... EREV PHEV40 2020 high Compact CNG 11.691 3.9796

Drag Parameters to view the values

Technical Accomplishments

Database Analysis Tool

Users can change parameters to perform uncertainty analysis without rerunning the simulations. For example, what is the impact of higher fuel cost, lower battery cost...?

The screenshot shows the 'Vehicle Database Analysis Tool' interface. On the left is a tree view of vehicle components. The main area displays a table of simulation results. A blue box labeled 'Modify Assumptions' points to the top of the table. Another blue box labeled 'Display plots of the data' points to the bottom left. A third blue box labeled 'Re-run calculations' points to the bottom right. The table has columns for Simulation, Vehicle Powertrain, Vehicle Class, Vehicle Year, Description of the simulation, Vehicle Cases, and Vehicle Fuel Type. The 'Price of Electricity (\$)' and 'vehicle Lifetime' columns are also visible. The status bar at the bottom indicates 'Displaying Information for 30 Simulations'.

Vehicle Database Analysis Tool

File Units

Drag and drop parameter to add it to a grid.

Search:

Filter: Drag and drop parameters from the tree view on the left and use them to filter which vehicle / simulation to load

Simulation Vehicle Powertrain Vehicle Class Vehicle Year Description of the simulation Vehicle Cases Vehicle Fuel Type

Assumption Main

Modify Assumptions

Simulation

Simulation	Vehicle Powertrain	Vehicle Class	Vehicle Year	Description of the simulation	Vehicle Cases	Vehicle Fuel Type	Price of Electricity (\$)	vehicle Lifetime
phev preliminary procedures_part4	erev_Compact_2020_high_9s_PT_40AER_cng.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Compact_2020_high_9s_PT_40AER_eth.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Compact_2020_low_9s_PT_40AER_cng.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Compact_2020_low_9s_PT_40AER_eth.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Compact_2020_med_9s_PT_40AER_cng.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Compact_2020_med_9s_PT_40AER_eth.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Midsize_2020_high_9s_PT_40AER_cng.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Midsize_2020_high_9s_PT_40AER_eth.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Midsize_2020_low_9s_PT_40AER_cng.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Midsize_2020_low_9s_PT_40AER_eth.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Midsize_2020_med_9s_PT_40AER_cng.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Midsize_2020_med_9s_PT_40AER_eth.a_vehicle						0.14	5
phev preliminary procedures_part4	erev_Midsize_SUV_2020_high_9s_PT_40AER_cng.a_vehicle						0.11311	5
phev preliminary procedures_part4	erev_Midsize_SUV_2020_high_9s_PT_40AER_eth.a_vehicle						0.11311	5
phev preliminary procedures_part4	erev_Midsize_SUV_2020_low_9s_PT_40AER_cng.a_vehicle						0.11311	5
phev preliminary procedures_part4	erev_Midsize_SUV_2020_low_9s_PT_40AER_eth.a_vehicle						0.11311	5
phev preliminary procedures_part4	erev_Midsize_SUV_2020_med_9s_PT_40AER_cng.a_vehicle						0.11311	5
phev preliminary procedures_part4	erev_Midsize_SUV_2020_med_9s_PT_40AER_eth.a_vehicle						0.11311	5
phev preliminary procedures_part4	erev_Midsize_SUV_2020_high_9s_PT_40AER_cng.a_vehicle						0.11311	5

Display plots of the data

Re-run calculations

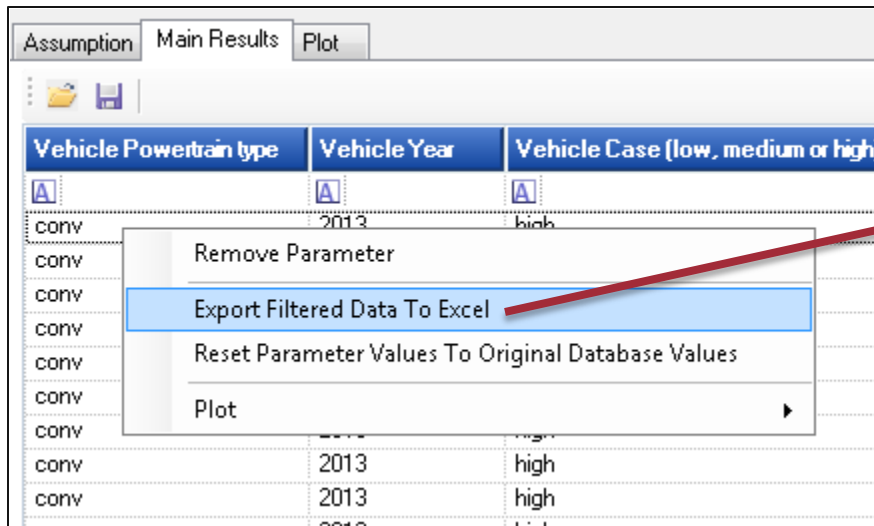
Calculate Processing Files Output Parameter Values

Displaying Information for 30 Simulations

Technical Accomplishments

Database Analysis Tool

Users can export subsets of the databases for further usage. Using that process, subsets have been created specifically to provide inputs to DOE VTO market penetration tools (i.e. MA3T, VISION...), GREET...



The screenshot shows an Excel spreadsheet with the same data as the Database Analysis Tool. The 'Vehicle Powertrain type' column is highlighted in blue. The data is as follows:

	A	B	C
	Vehicle Powertrain type	Vehicle Year	Vehicle Case (lo
1			
2	conv	2013	high
3	conv	2013	high
4	conv	2013	high
5	conv	2013	high
6	conv	2013	high
7	conv	2013	high
8	conv	2013	high

Technical Accomplishments

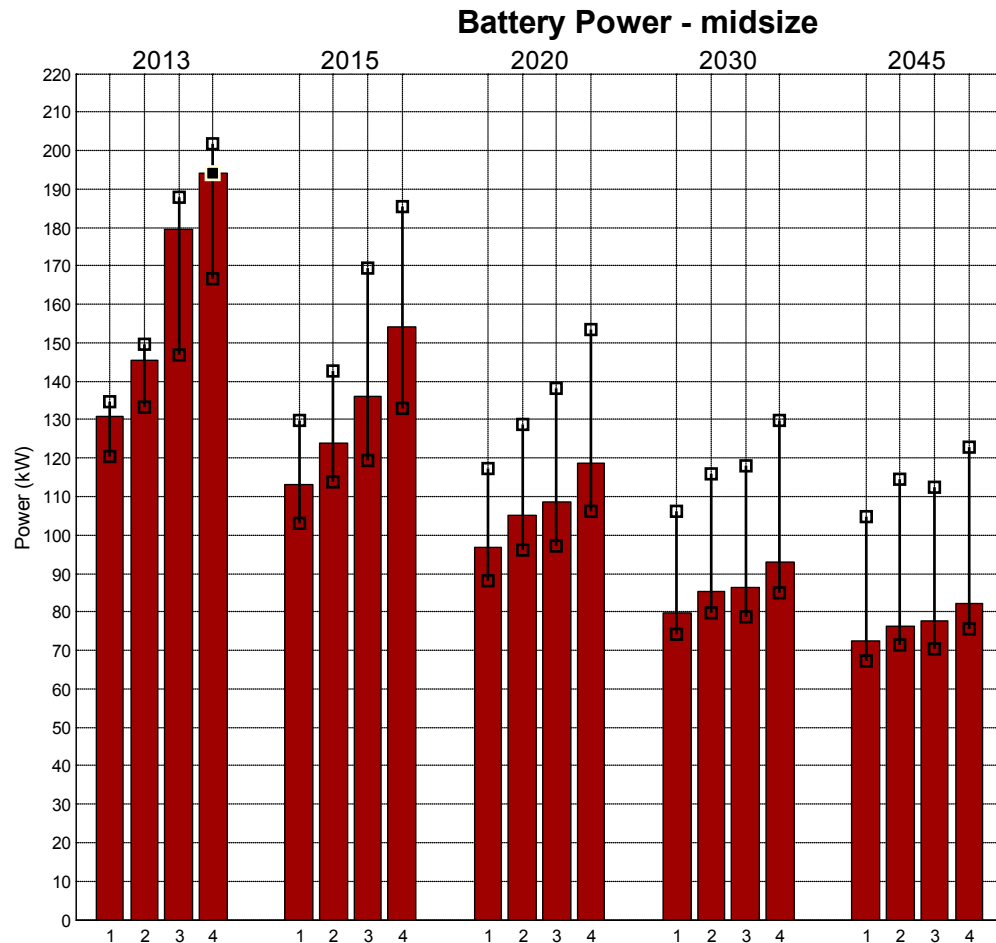
Generic Set of Pre-defined Plots Developed for Specific Components

Evolution of BEV Battery Power Requirements for a Midsize Car

Focus on one
Powertrain

Selected Filter

Class	Midsize
PT	BEV
Year	All
Case	All



4.bev300 elec fixedgear 300 aer
Class: midsize
bev300 elec fixedgear 300 aer
2013 - med
Power:194.25 kW

8.bev300 elec fixedgear 300 aer
Class: pickup
bev300 elec fixedgear 300 aer
2045 - med
Total Energy: 82.1794 kWh

- 1.bev100 dm elec 2dm 100 aer
- 2.bev100 elec fixedgear 100 aer
- 3.bev300 dm elec 2dm 300 aer
- 4.bev300 elec fixedgear 300 aer

4.bev300 elec fixedgear 300 aer
Class: midsize
bev300 elec fixedgear 300 aer
2013 - med
Power:194.25 kW

Technical Accomplishments

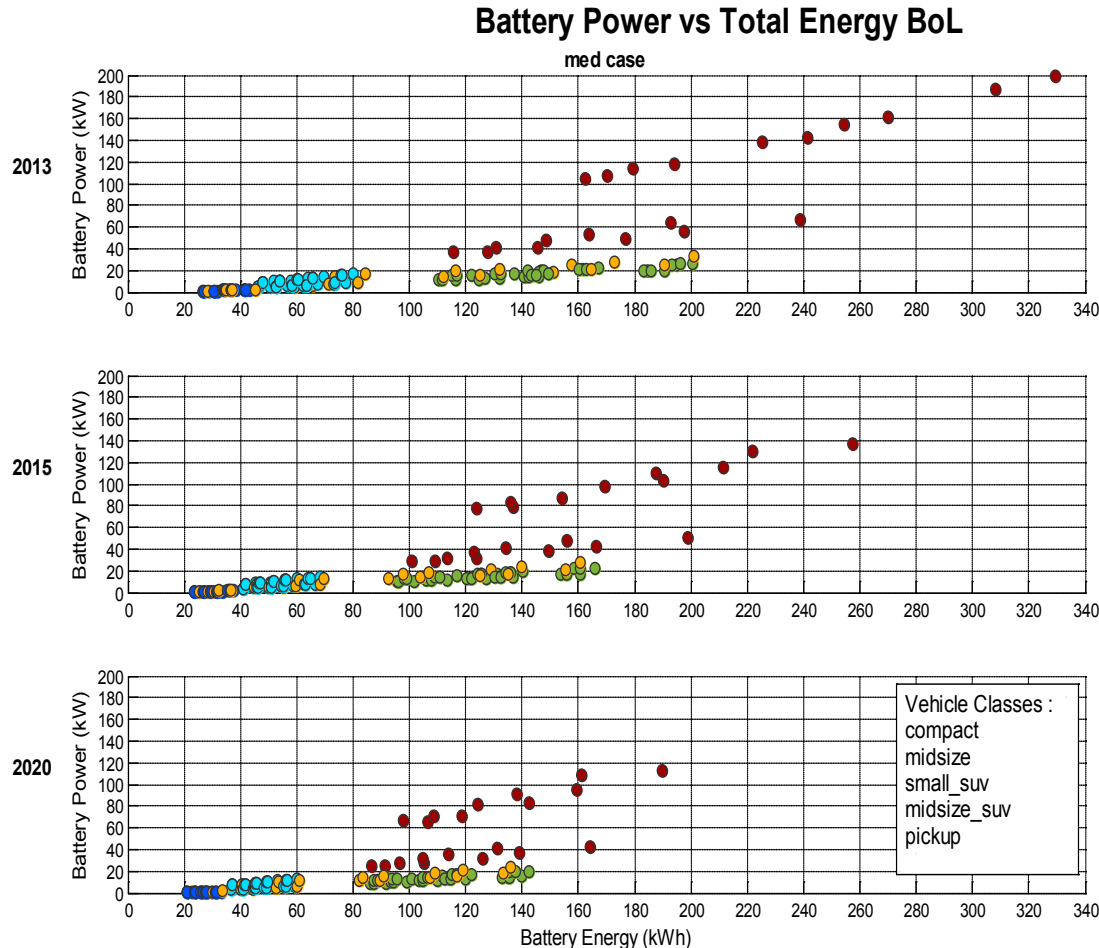
Generic Set of Pre-defined Plots Developed for Specific Components

Power to Energy Ratio – All Powertrains

Global Trend

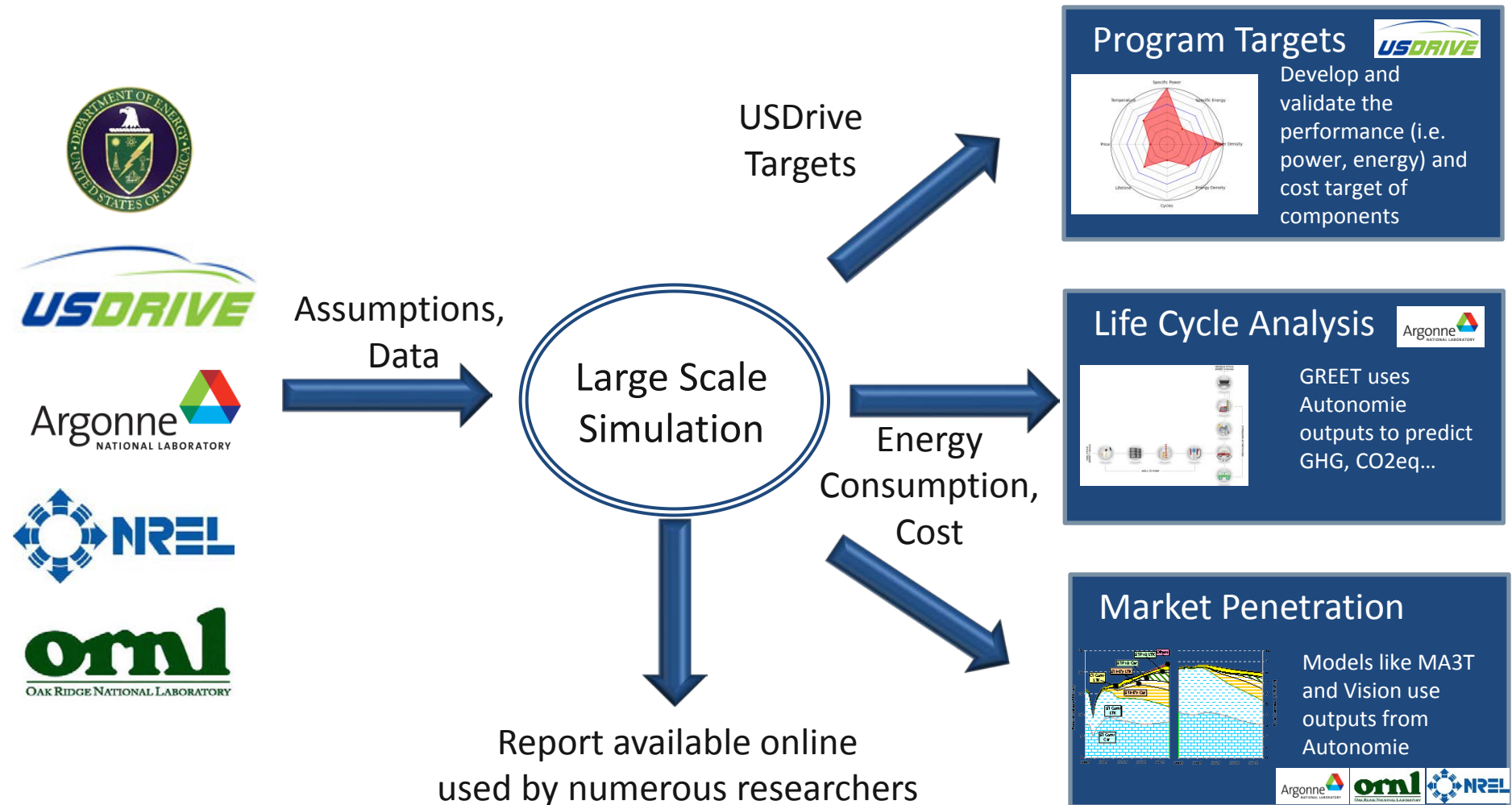
Selected Filter

Class	All
PT	All
Year	<2020
Case	Med

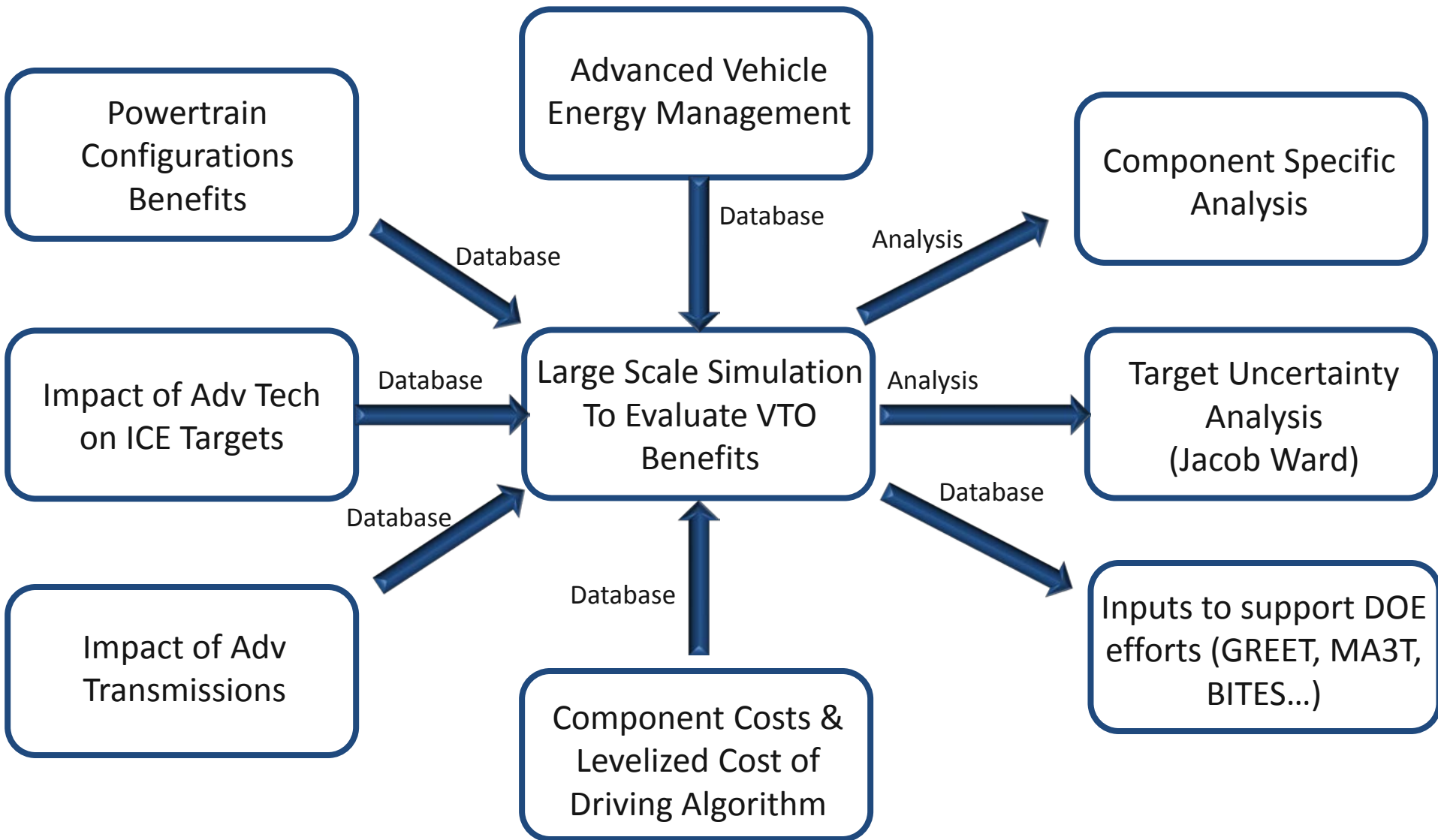


- split hev si planetary 0 aer
- split hev ci planetary 0 aer
- split hev cng planetary 0 aer
- split hev e85 planetary 0 aer
- split phv10 si planetary 10 aer
- split phv10 ci planetary 10 aer
- split phv10 cng planetary 10 aer
- split phv10 e85 planetary 10 aer
- split phv20 si planetary 20 aer
- split phv20 cng planetary 20 aer
- split phv20 e85 planetary 20 aer
- erev phv30 si voltec 30 aer
- erev phv30 ci voltec 30 aer
- erev phv30 cng voltec 30 aer
- erev phv30 e85 voltec 30 aer
- erev phv40 si voltec 40 aer
- erev phv40 ci voltec 40 aer
- erev phv40 cng voltec 40 aer
- erev phv40 e85 voltec 40 aer
- fc series hev h2 2dm 0 aer
- fc series phv10 h2 2dm 10 aer
- fc series phv20 h2 2dm 20 aer
- fc series phv30 h2 2dm 30 aer
- fc series phv40 h2 2dm 40 aer
- bev100 dm elec 2dm 100 aer
- bev100 elec fixedgear 100 aer
- bev300 dm elec 2dm 300 aer
- bev300 elec fixedgear 300 aer

Collaboration and Coordination with Other Institutions



Sample of Project Interactions



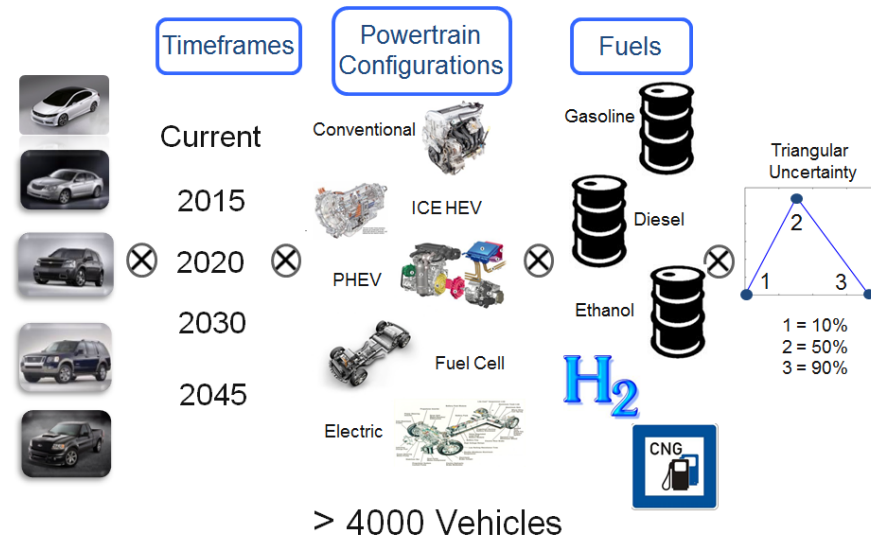
Proposed Future Work

FY14 Ongoing work

- Perform in-depth analysis of individual components working with each USDrive Technical Team
- Distribute database analysis tool to other Nat Labs (installation, documentation, etc.)

FY15 Proposed Activities

- Update the component and vehicle assumptions using expert inputs
- Run the complete study to evaluate the benefits of VTO technologies on vehicle energy consumption over multiple vehicle classes, timeframe, powertrain configurations, fuels, uncertainties....
- Improve the analysis process through the database analysis tool



Summary

- Due to the increased number of technologies being considered, the number of combinations that need to be evaluated has significantly increased over the last decade.
- As a result, a new process focused on analyzing very large data sets at both the vehicle and the component levels has been developed.
- The process allows in-depth analysis of individual component technologies (i.e., energy storage, engine, light weighting, electric machine, power electronics, fuel cell, hydrogen storage...).
- Future work will focus on updating the analysis to quantify the VTO R&D benefits based on the latest set of component and vehicle assumptions. New capabilities will also be added to the database tool to automatically generate HTML reports for each of the main components.